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INSTRUCTION MANUAL
for

DIGITAL MEASURING SYSTEM

MODEL DP-160
80 MEGAHERTZ
COUNTER PLUG-IN

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10514 DUPONT AVENUE • CLEVELAND, OHIO 44108

Printed in U.S.A.

MODEL DP-160
IN DMS
MAIN FRAME

MODEL DP-160 80 MEGAHERTZ COUNTER PLUG-IN

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DIGITAL MEASURING SYSTEM

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The Hickok Electrical Instrument Company warrants Digital Measuring System instruments of its manufacture to be free from defects in material and workmanship for one year (12 months) from the date of original purchase. Any instrument found to be defective during this period may be returned, transportation prepaid, to the factory for repair, or at our option, replaced without charge.

This warranty does not apply to any of our products which have been repaired or altered by unauthorized persons, or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced or removed. Neither shall the warranty apply where a warranty registration card has not been properly completed and returned to us promptly after purchase. This warranty is in lieu of all other warranties whether expressed or implied.

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19120-154

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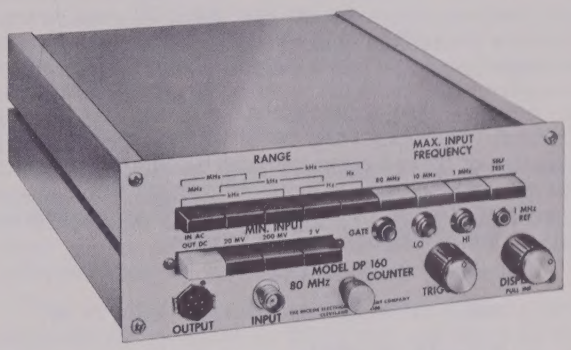
GENERAL INFORMATION

The type DP-160 80 Megahertz Counter Plug-in, when used with Digital Measuring System DMS Main Frame, provides numerical display of signal frequencies from 0.1 hertz to 80 megahertz. This highly accurate instrument features an overrange capability which allows seven digit resolution and an accuracy of ± .0005% ± 1 digit, including effects of ambient temperature variation, line voltage variation and line frequency variation over a range of 47 to 400 hertz.

Operator errors are greatly reduced by automatic decimal point location, overrange indication and color coded controls. Personnel inexperienced in the use of this type of instrument may obtain quick and accurate measurements with a minimum of training.

Loading errors are reduced by the high input impedance and can be further reduced by using the input attenuator or an isolation probe.

The DP-160 will easily and accurately measure frequency when applied in general laboratory, industrial and service situations.



Model DP-160 80 Megahertz Counter Plug-In

SECTION I
SPECIFICATIONS

Specifications.

DP-160 in DMS Main Frame.

Frequency Ranges*:

00.0 to 99.9 Hz
000. to 999. Hz
0.00 to 9.99 kHz
00.0 to 99.9 kHz
000. to 999 kHz
0.00 to 9.99 MHz
00.0 to 99.9 MHz

The last range is useful only to 80 MHz when used with DMS-3200 main frames; useful to 100MHz when used with DMS-3200A or DMS-3200P main frames.

*Unit may be overranged to provide up to 7-digit resolution.

Accuracy:

± .0005% ±1 digit - 15° to 40°C

± .00005% ±1 digit - short term accuracy at constant ambient temperature after calibration against NBS standard.

Drift less than 3.5 parts in 10^8 per week.

Input Impedance:

1 megohm shunted by 25pF

Overload Protection:

Accurate readings obtainable at voltages up to 200V RMS using internal attenuator. AC RMS input plus DC level must not exceed 600V.

Display Time:

Function of display adjustment and frequency RANGE in use. Pulling out the DISPLAY knob retains a reading indefinitely.

1MHz Reference:

100mV peak-to-peak. One megahertz reference oscillator.

Sensitivity:

Minimum RMS signal level: 20mV.

With X10 attenuator = 200mV.

With X100 attenuator = 2.0V.

Minimum pulse width: 4 nanoseconds.

Sine wave, square wave, non-symetrical waveforms.

Mounting:

Plugs into DMS-3200, DMS-3200A, or DMS-3200P Main Frames.

Power Requirements:

All power is supplied by the DMS Main Frame.

Size:

3" high, 8.25" wide, 10" deep.

Weight:

4.5 pounds (2.04 kg).

SECTION II
FRONT PANEL CONTROLS AND CONNECTIONS

Range Switch

The five interlocked push buttons designated RANGE select the reference time bases and correctly position the decimal point. The colored frequency designations above the RANGE SWITCH push buttons indicate the suffix which should accompany the figures displayed on the DMS main frame during direct measurements from 0.1 hertz to 80 megahertz (usable to 100MHz with DMS-3200A or DMS-3200P main frames). The MAXIMUM INPUT FREQUENCY switch consists of three interlocked push buttons whose colors correspond to the colored frequency designations over the RANGE switch. These buttons determine which range is being read, as follows:

Green - DC to 80MHz

Blue - DC to 10MHz

Red - DC to 1MHz

If desired, this reading can be converted to a time measurement by applying the formula:

$$\text{Time (sec)} = \frac{1}{\text{f(Hz)}}$$

Self-test Switch

The self-test switch is a push button interlocked with the MAXIMUM INPUT FREQUENCY switch. When depressed, an internally generated 100kHz signal is applied to the signal gate. The input circuitry is disconnected for this test.

Input Attenuator Switch

The MIN. INPUT switch consists of three interlocked push buttons which connect dividing networks into the circuit to divide the input by one, ten or one hundred. Next to, but not interlocked with, the MIN. INPUT switch is the AC-DC switch. When depressed, the input signal is AC coupled to the preamplifier.

Gate Light

The GATE light indicates when the control gate is open, allowing pulses to be counted.

Output

The OUTPUT, when connected to a Model DP-140 Slave Plug-in and a second DMS Main Frame, provides a six-digit display to the Digital Measuring System. When using the expansion capability, a reading is taken in the usual manner but the digits on the DP-140 and DMS Main Frame combination precede those on the DP-160 and DMS Main Frame combination. The decimal point placement is still automatic.

More information concerning the expansion capability may be found in the DP-140 Event Counter instruction book.

Input

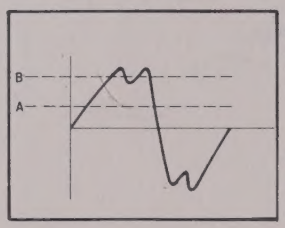
The input connector is a BNC type. The input may be either direct coupled or capacitively coupled to the preamplifier by operating the AC-DC switch. In the AC position, care must be taken to limit the peak AC amplitude plus the DC level to 600V.

The input impedance is 1 megohm shunted by 25pF; therefore, a standard 10:1 ratio, 10 megohm oscilloscope probe may be used if desired.

Level Control

The TRIGGER control sets the level at which the Schmitt-Trigger circuit switches. The lights above the TRIGGER control indicate the state of the Schmitt-Trigger circuit. In the presence of a signal of sufficient amplitude, the HI and LO lights will turn on alternately. (They appear to be on continuously if the frequency is above 30Hz). Therefore, the TRIGGER control should be adjusted until both lights appear to be on and a constant reading appears on the display.

Error can occur in the measurement of complex waveshapes where two or more major excursions exist during any half cycle. The unit will always trigger on any signal of sufficient amplitude. Therefore, the TRIGGER control must be adjusted so the Schmitt-Trigger circuit only triggers on the desired portion of the wave.



Setting trigger level at point A will result in the correct frequency reading.

Setting trigger level at point B will give an incorrect frequency reading

DISPLAY Control

This control determines the number of counting cycles which the instrument will perform in a given time interval. The length of display will vary with the frequency range. A reading may be held indefinitely by pulling out the DISPLAY control.

If the instrument is in the process of taking a reading when the knob is pulled, the reading will be completed and retained indefinitely. Pushing the DISPLAY control in causes normal readings to resume.

1MHz REFERENCE Output

A 100mV peak-to-peak one megahertz signal is supplied from the reference oscillator. The output impedance is 100 ohms. The output is fully protected and no damage will result if it is shorted to ground.

This output can be used as a stable reference or as a harmonic generator. A method of testing the calibration of the crystal oscillator is to use the output to heterodyne against the National Bureau of Standards radio station WWV.

SECTION III OPERATING INSTRUCTIONS

CAUTION: The BNC input terminal marked INPUT is isolated from third wire power line ground, not from the instrument case. If signals are to be measured with this terminal above ground, precautions should be taken to avoid a shock hazard. In normal operation, steps can usually be taken to avoid the necessity of operating the instrument above ground.

Always turn the DMS Main Frame off when inserting or removing plug-in units. (See note A.)

1. Insert the Model DP-160 Plug-in into the DMS Main Frame and secure it by means of the knurled knob in the center of the front panel.
2. Turn on the Main Frame, using the switch in the upper right corner of the Main Frame.
3. Allow one minute for the unit to stabilize. The unit will then be within its rated accuracy.
4. Press the SELF TEST button and the extreme left RANGE push button. A reading of 100 should appear on the display. Depressing any of the four buttons of the RANGE switch should result in a reading of 000 and an OVERRANGE indication.
5. Adjust the DISPLAY control until readings occur at a convenient rate. This should be done with the extreme left RANGE switch button pushed.
6. Press the IN AC and 2V MIN INPUT switches. Adjust the TRIGGER control until the LO and HI TRIGGER lights just switch states.
7. Connect the unknown signal to the INPUT. The signal must be greater than 20 millivolts RMS and less than 200 volts RMS. The LO and HI lights will turn on alternately if the signal is of sufficient amplitude. (They will appear to be on continuously if the frequency is greater than 30Hz.) If the TRIGGER indicators do not light alternately (or continuously), press the 200mV switch. If they still don't light press the 20mV switch. Always use the largest attenuation possible to prevent damage to the input circuitry. The minimum and maximum signal levels on the respective ranges are given in the table below.

MIN. INPUT Switch	Minimum Voltage	Maximum Voltage
20mV	20mV RMS	500mV RMS
200mV	200mV RMS	5V RMS
2V	2V RMS	200V RMS

8. Push the extreme left button in the RANGE switch. Push the 80MHz button of the MAX INPUT FREQUENCY switch. If the readout indicates the signal frequency to be less than 10MHz, push the 10MHz button of the MAX INPUT FREQUENCY switch. If the readout indicates the signal frequency to be less than 1MHz, press the 1MHz button. If the MAX INPUT FREQUENCY switch is set on a lower range than the input signal frequency, erroneous readings, random counts or no reading may result.
9. Select the lowest frequency on the RANGE switch that does not give an OVERRANGE indication. If this is done, the extreme left digit will not be zero.

   When operating the RANGE switch, the first reading after changing ranges should be ignored. The second reading and successive readings will be correct.

Display Time

The interval between readings is longer at lower ranges of frequency. The maximum reading time is 10 seconds for the fifth frequency range. A 10-second delay exists between readings. Be sure to allow sufficient time for the reading.

The reading displayed includes the decimal point, automatically positioned. Suffix this reading with the nomenclature above the depressed RANGE switch push button which is colored the same as the depressed MAX INPUT FREQUENCY switch push button. If increased resolution is desired, consult the "Procedure for Making Overrange Readings".

Use of Overrange Capability

The overrange capability of the DP-160 permits the instrument to display up to seven digit measurements with the three digit display through sector-reading of the measurement. This is simply the process of reading a portion of the measurement on one range and the balance on other ranges. Bear in mind that it is possible to obtain resolution in excess of the instrument accuracy. Table I lists the limits to which each range may be read with accuracy.

TABLE I

OVERRANGE RESOLUTION

MAX.INPUT FREQUENCY SWITCH	FREQUENCY RANGE	POSSIBLE DIGITS OF RESOLUTION WITH ACCURACY
80MHz *	0-80.0MHz *	7
10MHz	0-9.99MHz	7
1MHz	0-999.KHz	7
1MHz	0-99.9KHz	6
1MHz	0-9.99KHz	5
1MHz	0-999Hz	4
1MHz	0-99.9Hz	3

*Usable to 100MHz when operated with a DMS3200A or DMS3200P Main Frame

NOTE A: When using a buffer-storage type DMS Main Frame, place the MODE OF OPERATION SWITCH in the BUFFERED position. Use the NON-BUFFERED position for all other DMS Main Frames.

Procedure for Making Overrange Readings:

Since three digits are displayed at a time it is necessary to "build up" a final reading. This is done by recording a portion of each displayed reading as the RANGE switches are pressed from left to right and then obtaining a final figure from this series of recorded numbers. After a bit of practice the procedure becomes rather automatic but at the outset it is suggested that the following steps be followed in order to perform measurements logically and without error.

1. On a sheet of paper draw three vertical columns for recording data.

   (a) Title the first "COLUMN 1, READING NO.".

   (b) Title the second "COLUMN A, DISPLAYED READING".

   (c) Title the third "COLUMN B, FINALIZED READING".

2. Select the RANGE switch where a three-digit reading is obtained and the "OVERRANGE" indicator does NOT light.

3. RECORD THIS READING at A1 (Column A, Line 1). Include the decimal point and the "MHz", "KHz" or "Hz" suffice.

4. Press the next RANGE switch toward the right.

5. RECORD THIS READING on the next line of Column A. IF, AND ONLY IF, the center digit of the previous reading was "0" and the left-hand digit obtained in this step is "9", suffix this reading with a (-) sign.

   IF, AND ONLY IF, the center digit of the previous reading was "9" and the left-hand digit obtained in this step is 0, suffix this reading with a (+) sign.

6. Press the next RANGE switch toward the right.

7. REPEAT STEPS (5) and (6) until the overrange capability is exhausted or until sufficient resolution is obtained.

   AT THIS POINT THIS IS HOW A TYPICAL TABULATION OF A FREQUENCY MEASUREMENT WOULD APPEAR:

COLUMN 1 "Reading No."	COLUMN A "Displayed Reading"	COLUMN B "Finalized Reading"
1	852. KHz	
2	52.5	
3	2.57	
4	573.Hz	
5	73.9	

FROM THIS DATA WE CAN NOW BUILD UP OUR "FINALIZED READING"

8. Take the left-hand digit of the reading at A1 (Column A, Line 1) and record it at B1 (Column B, Line 1).

9. IF NO (+) OR (-) SIGN appears at reading A2: Take the digit obtained in Column B in the previous step and re-record this at B2. Directly to its right record the first digit of the reading at A2.

   IF A (+) SIGN appears at A2: Take the digit obtained in Column B in the previous step, mathematically add 1 digit, and record this digit at B2. Directly to its right record the first digit of the reading at A2.

   IF A (-) SIGN appears at A2: Take the digit obtained in Column B in the previous step, mathematically subtract 1 digit, and record this digit at B2. Directly to its right record the first digit of the reading at A2.

10. IF NO (+) OR (-) SIGN appears at reading A3: Take the digits obtained in Column B in the previous step and re-record them at B3. Directly to their right record the first digit of the reading at A3.

    IF A (+) SIGN appears at A3: Take the digits obtained in Column B in the previous step, mathematically add 1 digit and record these digits at B3. Directly to their right record the first digit of the reading at A3.

    IF A (-) SIGN appears at A3: Take the digits obtained in Column B in the previous step, mathematically subtract 1 digit, and record these digits at B3. Directly to their right record the first digit of the reading at A3.

11. Continue with this progressive recording until you arrive at the last reading. Record all of its digits instead of only the first. This gives a full multi-digit reading with maximum resolution.

    IN FINAL FORM THIS IS HOW THE TYPICAL TABULATION WOULD APPEAR

COLUMN 1 "Reading No."	COLUMN A "Displayed Reading"	COLUMN B "Finalized Reading"
1	852.KHz	8--.KHz
2	52.5KHz	85-.
3	2.57KHz	852.
4	573.Hz	852.5
5	73.9Hz	852.5739 KHz (final)

HERE IS ANOTHER TYPICAL TABULATION

1	600.KHz	6--.KHz
2	99.8KHz (-)	59-.
3	9.80KHz	599.
4	799.Hz	599.7
5	00.0Hz(+)	599.8000 KHz (final)

HERE IS ANOTHER TYPICAL TABULATION

COLUMN 1	COLUMN A	COLUMN B
1	700.KHz	7--.KHz
2	99.9KHz (-)	69-.
3	0.00KHz(+)	700.
4	999.Hz(-)	699.9
5	00.0Hz(+)	700.0000KHz (final)

Measurement in Presence of Line Transients

The power supplies in the DMS Main Frame are regulated to eliminate most difficulties due to line transients. Extreme transients however, will affect any instrument with the sensitivity of the DP-160. The symptoms are usually spurious readings which are rarely the same for any consecutive readings. Connecting the chassis to earth ground will help to eliminate these errors.

Measurement in High Electric or Magnetic Fields

Extreme electro-magnetic phenomena can cause false triggering of the instrument. The difficulties can sometimes be overcome by connecting the chassis to earth ground.

When using the DP-160 to measure very low frequency signals, any susceptibility to spurious phenomena is a drawback. The degree of susceptibility of the unit is due to its high sensitivity and can be reduced by using the MIN. INPUT attenuator switch. If problems persist, contact the Hickok Electrical Instrument Company for special assistance in eliminating the difficulties.

SECTION IV
THEORY OF OPERATION

Before describing the individual circuits of the DP-160, a brief description of digital measurement of frequency will be given.

Frequency can be measured accurately by counting the number of cycles in a precisely controlled time interval.

Figure 1 shows a block diagram of a typical frequency meter scheme. The input is amplified and shaped in order to present pulses of uniform amplitude and rise-time to the decade counters.

The signal gate controls the flow of the shaped pulses to the decade counters. When a pulse from

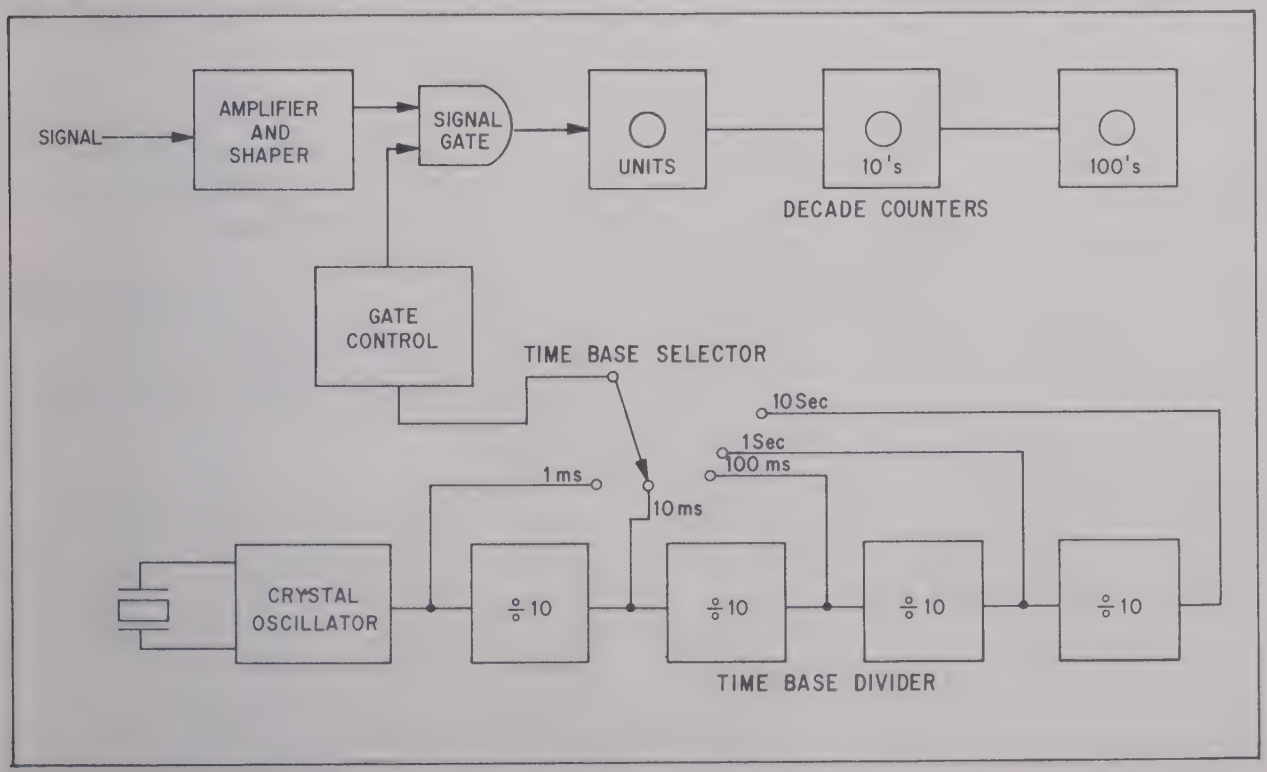


Figure 1. Frequency Meter Block Diagram

the time base divider opens the signal gate, the shaped pulses pass through and are counted by the decade counters. At the end of the precisely controlled time interval, a pulse from the time base divider closes the signal gate.

Gating Error

Since the opening and closing of the signal gate is rarely synchronized with the signal passing through the gate, there always exists a ±1 count gating error. In figure 2, line C represents the opening of the signal gate. If the phase relationship of the incoming signal with respect to the gate is shown by line A, six pulses will be counted. However, if the phase relation is as shown in line B, only five pulses will get through the open signal gate. This may become an appreciable error when measured in percent. A frequency measurement of a 10Hz signal would have an inherent inaccuracy of ±10% due to gating error. For this reason, period measurements are normally preferred over frequency measurements at low frequencies.

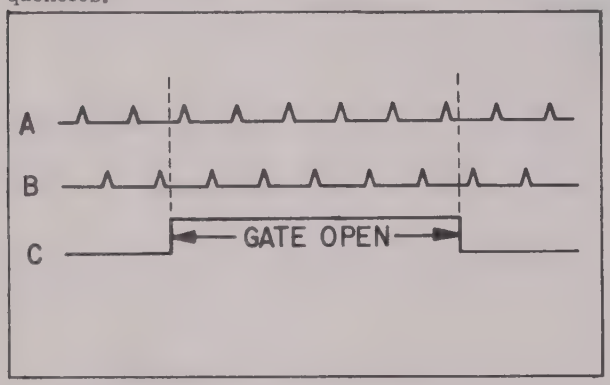


Figure 2. Gating Error

Time Base Error

The time base determines the opening and closing of the signal gate. Therefore, inaccuracies in the time base cause errors in measurements. Time-base errors consist of oscillator-calibration errors, short-term crystal stability errors and long-term crystal stability errors.

The most accurate method of crystal calibration is to zero-beat the crystal oscillator against the frequency-standard radio station, WWV. This can usually be done to an accuracy of one part in 10^6. If the zero-beating is done with visual rather than audible means, the calibration accuracy can usually be improved to one part in 10^7.

Short-term crystal stability errors are caused by momentary frequency variations due to voltage transients, shock and vibration, electrical interference, etc. These errors can normally be minimized by taking frequency measurements over long gate times.

Long-term stability errors are probably the most subtle contributors to the inaccuracy of a frequency measurement. Long-term stability is a function of crystal aging. As the crystal is temperature-cycled and kept in continuous oscillation, internal stresses induced during manufacture are relieved and minute particles adhering to the surface are shed. Generally, these phenomena will cause an increase in the oscillator frequency.

Conclusion

Maximum accuracy can be obtained from digital frequency measurements if the following suggestions are followed:

1. The effect of the ± 1 count gating error can be minimized by making frequency measurements above $\sqrt{fc}$ where fc is the clock frequency.

2. Since the long-term oscillator stability has a cumulative effect, accuracy of the measurement is mostly a function of time, since the last calibration against a primary or secondary standard.

With a basic understanding of the operations necessary to measure the frequency of a signal, one can now proceed to the circuit operations of the DP-160.

The system consists basically of three sections. They are the input and signal standardization circuits, the precision time base, and the gating circuits. Each section will be covered individually.

Input Attenuator

The input attenuator consists of four switches. The white pushbutton is used to select AC or DC coupling of the input to the amplifier. Depressing this switch AC couples the input through a 0.1 microfarad 600 volt coupling capacitor.

The other three switches are used to attenuate the input signal by a factor of 1, 10 or 100. This allows large signals to be measured without exceeding the maximum amplifier input voltage. The input impedance of the amplifier remains at essentially 1 megohm shunted by 25 picofarads regardless of the attenuation.

Amplifier

The amplifier is direct coupled and utilizes two DC feedback paths to maintain temperature stability. Individual stage degeneration is used to determine the AC gain. The AC gain is approximately 25. One DC feedback loop is also used to control the trigger level of the shaping circuit. This provides stable triggering over the entire temperature range.

The input impedance of the amplifier is the impedance of the first FET. This impedance is a minimum of 100 megohms at 100℃ shunted by 4 pf capacitance.

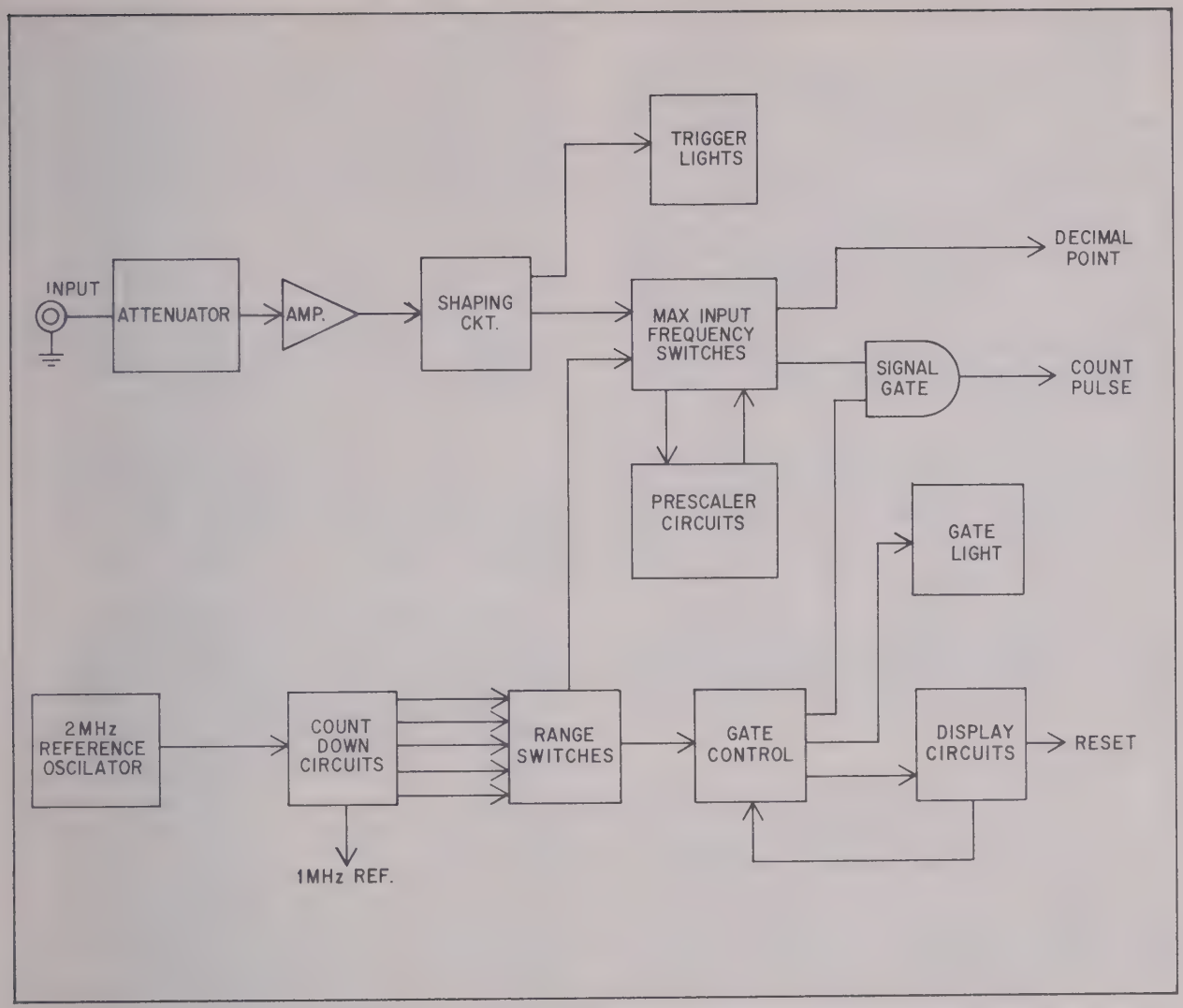


Figure 3. Block Diagram of DP-160 Measurement Circuits

Shaping Circuit

The shaping circuit is basically an emitter coupled current mode logic gate with positive feedback. This regenerative type circuit provides pulses with extremely fast rise and fall times and shifts the output level of the preamplifier such that it is compatible with MECL type logic.

The operation of the circuit is basically that of a Schmitt Trigger. With the input to Q23 low, transistor Q24 is turned on. This results in Q26 being on and the output of Q27 being at a logic "1" level. When the input to Q23 is high, the current through Q23 increases and the cycle is reversed. The hysteresis of this circuit is approximately 600 millivolts.

The output of the shaping circuit is approximately 900 millivolts. This can be viewed at test point Q.

Trigger Level Lights

The trigger lights control circuit is a cascode differential amplifier circuit containing high voltage breakdown transistors which are capable of driving the neon lamps directly. Transistors Q29 and Q31 form the differential amplifier which accepts the same input signal as MECL logic. In this way, the circuit operates on the output of the shaping circuit.

The trigger lights appear to remain on continuously when the signal frequency is greater than 30Hz, but the circuit is actually switching at the same rate as the circuit.

This circuit is direct coupled to the shaping circuit output. Therefore, the lights are used to indicate the state of the shaping circuit.

Prescalers

The DMS Main Frame is capable of counting at a maximum rate of 1 megahertz. Therefore, the signal must be scaled before it reaches the main frame.

This unit contains two prescalers, one which divides by 8 and one which divides by 10. The divide-by-8 circuit consists of three MECL J-K flip-flops M16, M17 and M18 connected as divide-by-2 circuits. MECL circuits were chose for their high frequency capability. The divide-by-10 circuit, M19, is an integrated circuit decade counter, containing DTL type logic. A level translater, consisting of Q33, Q34, and Q35, is required between the MECL and DTL type circuits.

The level translater is also an emitter coupled current mode logic gate with a saturated switch-type (Q35) on its output. This circuit is designed to accept input signals from either the MECL logic or the shaping circuit. Its output is capable of driving the decade counter, M19, or the signal gate. This output can be viewed at test point S.

Switching the prescalers out of the circuit and using the level translater directly results in greater resolution of the unit. In fact, the resolution is the same between 1 and 80 megahertz.

Reference Oscillator

The 2MHz reference oscillator is a transistorized crystal controlled type in which the crystal operates as a parallel-resonant circuit. This crystal controlled oscillator is used as the frequency standard for the control gate. It can be adjusted very accurately to the reference frequency by varying C1. Its accuracy is better than 5 parts per million over the temperature range of 20°C to 55°C. This output can be observed at the collector of Q2.

Another output, marked "1MHz REF." on the front panel, can be used to check this circuit. This output is one-half the reference oscillator frequency.

Countdown Circuits

The DP-160 contains 8 standard frequency sources which are synchronized with the 2MHz reference oscillator. Only 5 of the 8 sources are used for the control gate. The other 3 are used to reduce the frequency to the desired value. Each source, except 1 and 2, is one decade below the preceding source. The second source either divides by 8 or 10, depending on which MAX. INPUT FREQUENCY switch is depressed. It counts by 8 when the 80MHz switch is depressed and by 10 when any other switch is depressed. The first source divides by 2.

The sources are derived by counting down the frequency from the previous source, using a minimum element modulo 10 counter. Six of the divide-by-10 blocks are stacked between + 20 volts and ground. The signal is capacitively coupled from one stage to the next. The connections for these divide-by-10 circuits are shown on the wiring diagram.

Control Gating

The control gating circuitry is a group of dual input NOR gates, AR1 and AR2 connected as a set-reset flip-flop and a J-K flip-flop with expanded clear inputs. An input to one side of the set-reset unit is derived directly from a source within the 1kc countdown. The other input is switched through the RANGE switches. Therefore, this circuit has an inherent 400 microsecond time delay from the points in the countdowns where the gate signal is derived. The circuits are reset during this delay. When viewing this waveform on an oscilloscope, the positive pulse becomes a small segment of the overall time base and will become difficult to see on the 1 and 10 second gate waveforms.

The output waveform of the set-reset flip-flop is of the same time duration as the gate time for the selected range. This portion of the circuit runs continuously. In order to display a reading for a sufficient period of time to be viewed, a display time cycle must be incorporated into the operation of the unit.

The DISPLAY circuitry develops a time delay during which no readings are taken. A unijunction transistor (Q6) has a controllable R-C time constant (variable by R32) in its emitter circuit. When the voltage on the emitter reaches a point which will fire Q6, the unijunction is held off by Q7 until a synchronizing signal is injected into the base of Q7, allowing Q6 to fire. The synchronizing signal is derived from two sources. One is from the gate control J-K flip-flop. This indicates to the DISPLAY circuitry that the unit is not in the process of taking a reading. The other signal is from the set-reset flip-flop. This signal synchronizes the display circuitry with the set-reset flip-flop, thereby controlling the reset pulse such that it occurs only at the beginning of the read cycle.

The display unijunction Q6 can only fire in synchronism with the positive rise of the set-reset flip-flop. When the unijunction fires, a negative voltage is developed on the base of Q40. This turns off Q40 for a period of time determined by the R-C charging rate of R102 and C55. The time delay is approximately 10 microseconds. When the set-reset flip-flop returns to its normal state, Q7 is turned off, thus shutting off Q6 and terminating the reset pulse.

When the set-reset flip-flop turns off, the negative going pulse is transferred by C17 to the J-K flip-flop. When the J-K flip-flop is in the display state, the pulse is transferred to its output. If the display circuitry has not fired, Q40 simply shorts this output to ground and no state change occurs in the J-K flip-flop. When the display circuitry has fired, Q40 is turned off and the pulse is transferred to the output of the J-K flip-flop. This removes the voltage to the signal gate and begins the read cycle.

The signal gate is a NOR gate; that is, it requires both inputs to be at logic "0" for a logic "1" to appear at its output. If one or the other, or

both, inputs are at logic "1", the output is at logic "0". This characteristic is used to operate the circuit as a signal gate. One input of the signal gate is controlled by the J-K flip-flop. The other input is from the prescaler circuits. If the input from the J-K flip-flop is logic "1", then the output is logic "0", regardless of what the other input is. When the input from the J-K flip-flop is logic "0", then the output will be controlled by the state of the other input.

The output of the signal gate is amplified by Q4 and goes to the main frame counting circuits. For the GATE open position, the input to the signal gate from the J-K flip-flop is held at logic "0" and the signal appearing at the other input goes through the signal gate and amplifier to the main frame.

Overrange Capability

A procedure to obtain overrange readings is presented in the section on Operating Instructions. This portion deals with what happens internally.

The main frame requires 999 pulses for a three-digit reading without overranging. Beyond this point, it will count normally but will not display applicable left-hand digits. Therefore, in measuring signals for a full scale reading (overrange indicator off), the shortest RANGE time is scaled to allow a three-digit reading (from 100 to 999 pulses) to enter the main frame.

An example can best illustrate the inherent overrange capability of the DP-160.

Assume the 1MHz MAX. INPUT FREQUENCY switch is depressed and the input frequency is 763, 158.7 cycles per second. Using a GATE time of 1 millisecond will allow 762, 763 or 764 pulses to enter the main frame. The reading will then be 762., 763. or 764. "kHz". This is the first three digits ±1 digit of the frequency to be measured.

Then switch to the next RANGE switch which is a 10 millisecond GATE time. It is easily seen that 7630, 7631 or 7632 pulses will enter the main frame in that time period. The main frame will count these pulses and, after passing 999 the first time, will turn the overrange indicator on. The final reading will be 63.0, 63.1 or 63.2 "kHz" with the overrange indicator ON. Note that these are the second, third and fourth digits ±1 digit on the input frequency.

This process can be continued through the available RANGE positions, thereby obtaining successive three-digit portions of the input frequency. The ±1 digit characteristic requires that the reading be "built", using the left-hand digit or left and center digit.

SECTION V
SERVICE PROCEDURE

Servicing the DP-160 plug-in should be attempted only after the section of the manual entitled "Theory of Operation" has been read and understood. Trouble-shooting can be divided into four basic categories;

1. The countdown circuitry, including the signal and control gate and the display circuitry. This section includes Q1 through Q10, Q40, M1 through M15, AR1, AR2 and associated circuitry.

2. The preamplifier and shaping circuitry. This includes the attenuator switch, Q11 through Q21, Q23, Q24, Q26, Q27 and associated circuitry.

3. The prescaler circuits including the MECL-to-saturated logic level translater. This includes M16 through M19, Q33, Q34, Q35 and associated circuitry.

4. The RANGE and MAX. INPUT FREQUENCY switches.

Servicing can be accomplished most conveniently by removing the back of the DMS Main Frame and sliding out its bottom plate. With the DMS Main Frame upside down and the DP-160 bottom cover removed, easy access to all circuitry is provided.

Prior to checking any electronic circuitry, check for correct voltage at the following suggested points with respect to ground.

1. + 20 ± .1 volt at Pin 3 (main connector).

2. -20 ± .1 volt at Pin 11 (main connector).

3. + 19 ± .5 volt at emitter of Q22.

4. -19 ± .5 volt at emitter of Q23.

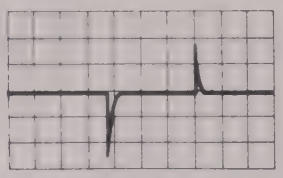
5. + 5.1 ± .2 volt at emitter of Q36.

6. -5.1 ± .2 volt at emitter of Q38.

7. + 3.6 ± .2 volt at emitter of Q25.

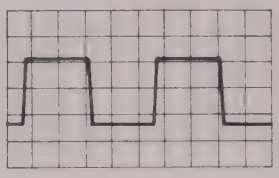
1. The Countdown Circuitry

This circuitry may be serviced independently of the remaining section. With the unit turned on and the 1MHz MAX. INPUT FREQUENCY switch depressed, waveforms similar to the one shown for test point G should appear at the output of each ÷ 10 circuit. The period of each ÷ 10 circuit will increase by a factor of 10 from the previous circuit. If one of the divide by 10



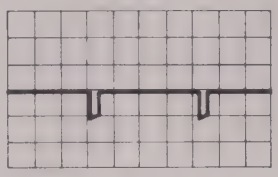
TEST POINT A

.5V/cm
.1m sec/cm



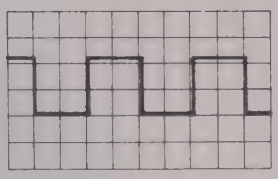
TEST POINT F

.5V/cm
.2 μsec/cm



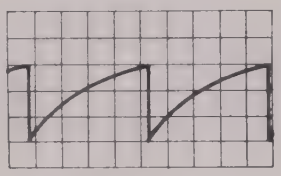
TEST POINT B

.2V/cm
2M sec/cm



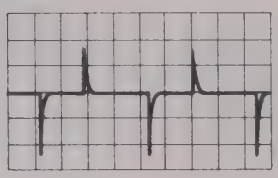
TEST POINT G

.5V/cm
2 μsec/cm



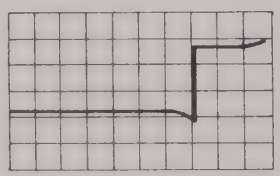
TEST POINT C

2V/cm
.2 sec/cm



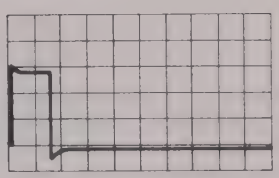
TEST POINT H

.5V/cm
.2 m sec/cm



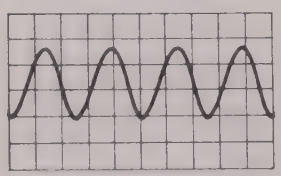
TEST POINT D

2V/cm
.1m sec/cm



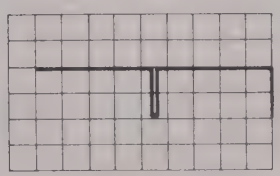
TEST POINT J

.5V/cm
.2 m sec/cm



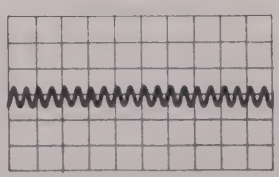
TEST POINT E

2V/cm
.2 μsec/cm



TEST POINT K

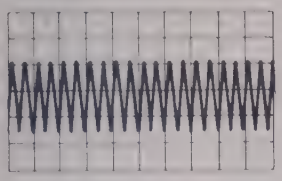
.5V/cm
.2 sec/cm



TEST POINT L

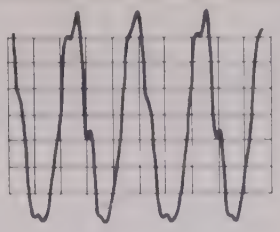
.05V/cm
100 n sec/cm

Figure 4. DP-160 Waveforms (Sheet 1 of 2)



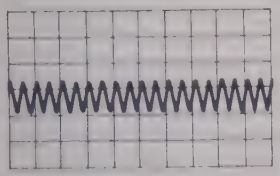
TEST POINT M

.1V/cm
.1 μsec/cm



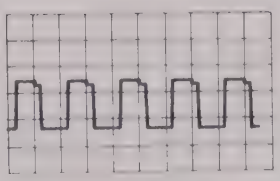
TEST POINT Q

20.MV/cm
5 n sec/cm



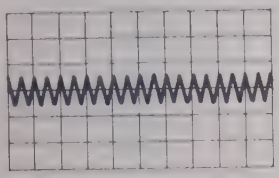
TEST POINT N

1V/cm
100 n sec/cm



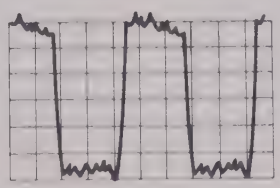
TEST POINT R

.5V/cm
200 n sec/cm



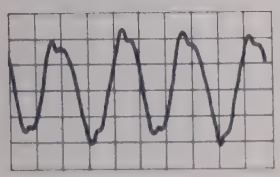
TEST POINT P

1V/cm
100 n sec/cm



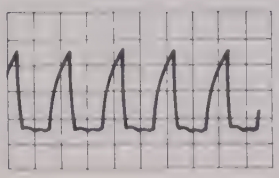
TEST POINT R

.1V/cm
20 n sec/cm



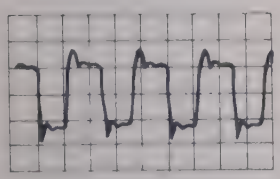
TEST POINT P

.5V/cm
5 n s/cm



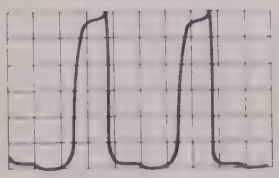
TEST POINT S

1V/cm
50 n sec/cm



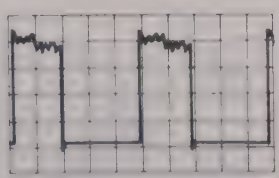
TEST POINT Q

.5V/cm
20 n sec/cm



TEST POINT S

1V/cm
100 n sec/cm



TEST POINT T

1V/cm
200 n sec/cm

Figure 4. DP-160 Waveforms (Sheet 2 of 2)

circuits does not function, check the voltage across each couplet.

M1 through M12 are connected in series across the + 20 volt supply. The voltage across each divide by 10 circuit should be greater than 3.2 volts and less than 3.6 volts.

Waveforms shown at test points A, B, C, D, H, J and K show typical circuit operation when the extreme left RANGE switch is depressed. The repetition rate decreases as the other RANGE switches are depressed.

2. Preamplifier and Shaping Circuitry.

To check this portion of the circuitry at its maximum frequency capability requires a Tektronic Type 561 sampling oscilloscope or its equivalent.

The preamplifier and shaping circuit can be checked most easily by changing the TRIGGER level. If the circuit functions normally, the LO light will light when the TRIGGER control is rotated counterclockwise and the HI light will light when the control is rotated clockwise. If the lights do not change, check the DC voltages back through the shaper and preamplifier circuits.

The output of the shaper, at test point Q, varies nominally between -0.8 and -1.9 volts. The output of the preamplifier, at test point P, can be varied nominally between -1.3 and -4.1 volts.

Waveforms with 20 millivolts signal at 20 megahertz and 80 megahertz are shown in Figure 4.

The input attenutator is very sensitive to capacitive loading. Therefore, it must be checked at the output of the preamplifier. (Test point P). Waveforms at this test point are shown in Figure 4. This amplitude should remain essentially constant when the input signal is increased by a factor of 10 and the next larger MIN. INPUT attenuator is pressed.

3. Prescaler Circuits.

The prescaler consists of a divide by 8 circuit and divide by 10 circuit. The divide by 8 circuit consists of three current mode high speed flip-flops. Each unit divides by 2. A typical waveform is shown in Figure 4 at test point R.

The level translater used between the prescalers is a current mode differential amplifier with a saturated stage on its output. The reference level for this circuit is determined by R96 and R97 and is nominally -1.1 volts. This circuit can be checked with the TRIGGER control. Depress the 1MHz MAX. INPUT FREQUENCY switch. The output at the collector of Q35 should switch state every time the level lights change state. Waveforms are shown of the level translater output at two frequencies in Figure 4.

The divide by 10 circuit M19 is an integrated decade counter. Its output waveform is shown at test point T on Figure 4.

4. Switches

The push button switch interconnections are shown on the schematic wiring diagram.

Visually inspect the points at which these switches connect to the printed circuit board or to other components. With the exception of repair of physical damage, no service to the switches should be required.

SECTION VI
CALIBRATION

The DP-160 has only one calibration adjustment. This adjustment is the 2MHz reference oscillator. After initial calibration, this needs adjustment periodically to compensate for crystal aging.

Equipment Required

1 counter with time base accuracy better than ± 2 parts in 10^7. (Hewlett-Packard 524C or equivalent.)

Procedure

1. Plug the Model DP-160 into a Model DMS Main Frame, which has its bottom cover removed, and turn it on.
2. Allow the unit to warm up for 30 minutes.
3. Connect the counter to the 1MHz REF. Use the 10-second gate and adjust C1, through the hole in the bottom cover, until a reading of 1,000,000.0Hz ±1 count is obtained.

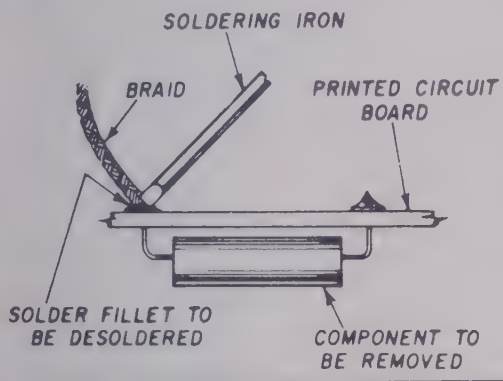
Alternate Procedure

An alternate method of calibrating the 2MHz reference oscillator is by beating its output against WWV. Using a good receiver, tune in WWV on any of its reference frequencies greater than 5MHz. Connect approximately 10 feet of wire to the 1MHz REF jack. Adjust C1 until a zero beat is heard on the receiver.

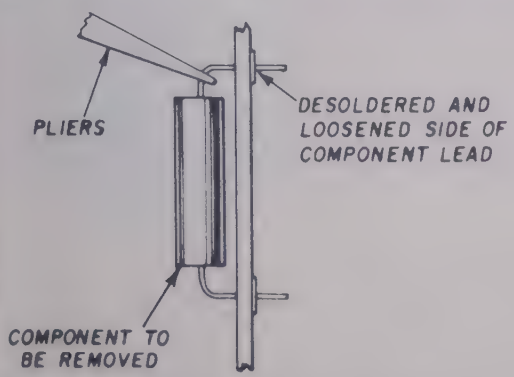
PROCEDURE FOR REPLACING COMPONENTS IN PRINTED CIRCUIT BOARDS

1. Place printed circuit in the horizontal position with the soldered side up*. Take a length of fine braid or fine stranded wire either tinned or not tinned. Braid is preferable. Dip the end of the braid in resin flux (London Chemical Co. type #77-33-TA or equivalent). Placed the fluxed end of the braid on a solder fillet of the component to be removed. Press the braid on to the fillet using the clean tip of the soldering iron. Do not overheat the board or component. Only heat the solder fillet sufficient to melt the solder. The solder will "wick" up the braided wire removing the solder from the joint. Continue this process until all leads of the component to be removed are free of solder.

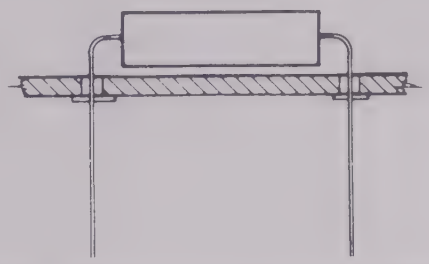
*A SOLDAPULLT desoldering tool, manufactured by Edsyn Inc., can be used in place of stranded wire.



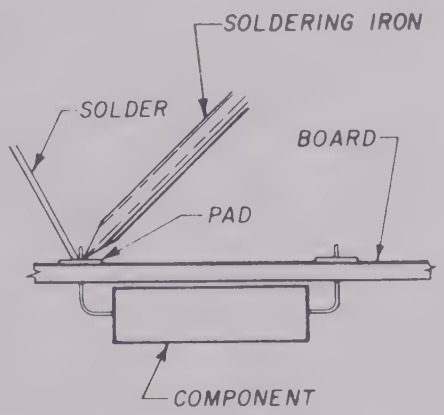
2. Using a pair of needle nose pliers "wiggle" each lead of the component to be removed to be sure it is free of the land area to which it was soldered. Place the needle nose pliers on the component lead and remove the lead. Continue the procedure with each component lead until the component is removed. Do not force the leads. If a lead can not be removed touch the lead on the soldered side of the board with the soldering tip.

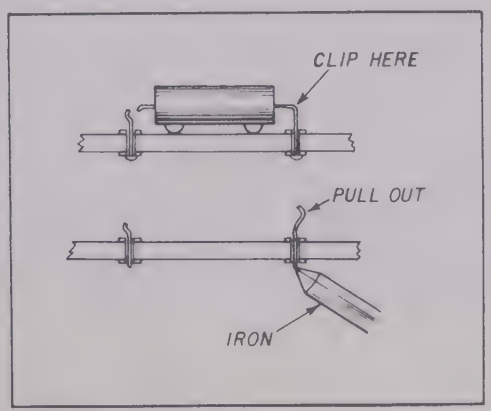


3. Bend clean tinned leads of new component and carefully insert in holes. (Do not force component. If it does not insert easily reheat pad and clean as before).



4. Hold part to board and solder leads from print side of board. Do not leave a large blob of solder on pad. The correct amount can be determined by observing other connections made in production.





Clean holes with a piece ot .020 stainless steel wire by melting the solder and poking the wire through.

The above should be carefully followed or extensive damage to the printed circuit board will result.

Figure 5. Servicing Etched Circuit Boards

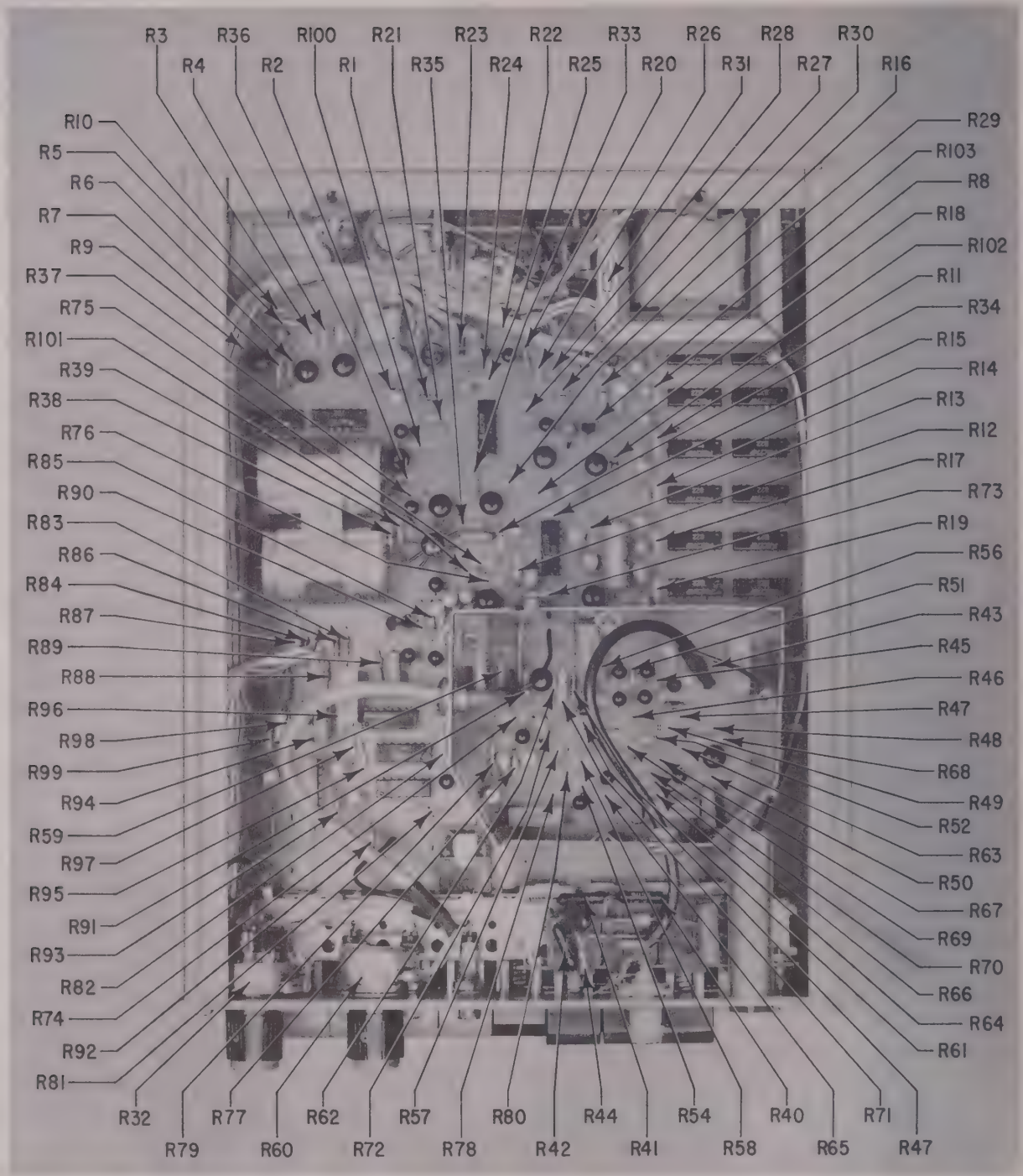


Figure 6. Component Locations (Sheet 1 of 2)
Resistors Only

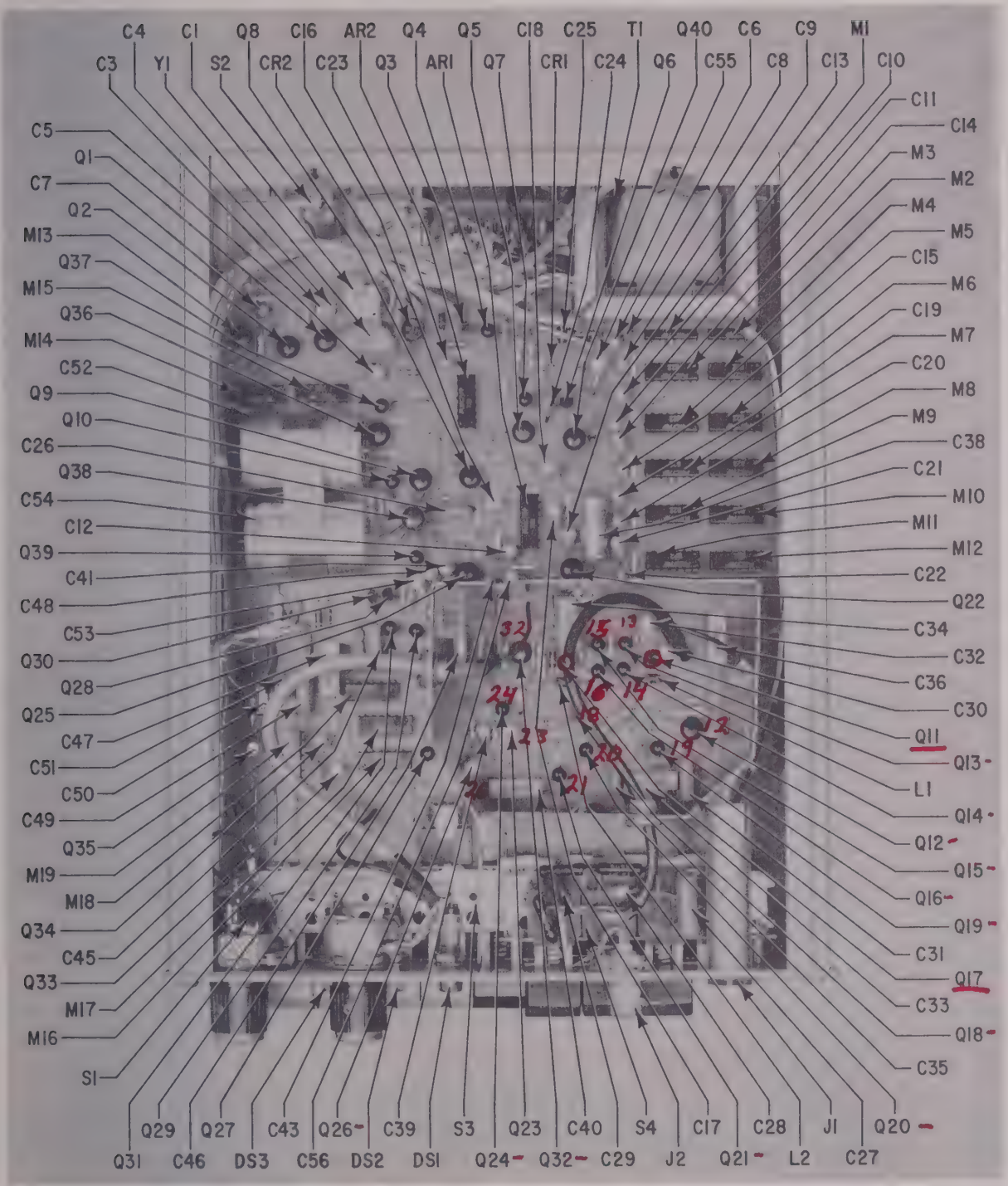


Figure 6. Component Locations (Sheet 2 of 2)
Other Components

SECTION VII PARTS LIST

Reference designations have been assigned to identify all parts used in this instrument. An asterisk designates a part which should be replaced by authorized Hickok repair stations or factories. It is therefore recommended that the entire instrument be returned for repair if trouble exists with such a part.

In ordering parts, refer to the current parts price list for this instrument. Prices are subject to change without notice, and the minimum billing charge is $3.50.

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
AR1, AR2	INTEGRATED CIRCUIT: MC717P	9800-2
C1	CAPACITOR, VARIABLE: trimmer, 2-22 pF, E. F. Johnson #189-508-5	3115-72
C2	CAPACITOR, FIXED, POLYSTYRENE: 33 pF, 5%, 125 volts	3100-330
C3	CAPACITOR, FIXED, POLYSTYRENE: 1000 pF, 5%, 125 volts	3100-102
C4	CAPACITOR, FIXED, POLYSTYRENE: 100 pF, 5%, 125 volts	3100-101
C5	CAPACITOR, FIXED, CERAMIC: 470 pF, 20%, 500 volts	3111-520
C6	CAPACITOR, FIXED, ELECTROLYTIC: 22 μF, 6 volts	3085-316
C7	CAPACITOR, FIXED, CERAMIC: 1000 pF, +50, -20%, 500 volts	3111-522
C8	CAPACITOR, FIXED, CERAMIC: 330 pF, 20%, 500 volts	3111-519
C9	Same as C6	
C10	Same as C8	
C11	Same as C6	
C12 thru C14	Same as C8	
C15	Same as C6	
C16	CAPACITOR, FIXED, CERAMIC: 4700 pF, +50, -20%, 500 volts	3111-526
C17	Same as C5	
C18	Same as C16	
C19	Same as C8	
C20	Same as C6	
C21	Same as C8	
C22	Same as C6	
C23	CAPACITOR, FIXED, CERAMIC: 220 pF, 20%, 500 volts	3111-518
C24	CAPACITOR, FIXED, CERAMIC: 22 pF, 20%, 500 volts	3111-512
C25	CAPACITOR, FIXED, ELECTROLYTIC: 5 μF, 20 volts	3085-269
C26	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .01 μF, 10%, 200V	3092-201
C27	CAPACITOR, FIXED, POLYCARBONATE: .1 μF, 20%, 630 volts	3092-613
C28	CAPACITOR, FIXED, COMPOSITION: 1.8 pF, 10%, 500 volts	3116-6
C29	CAPACITOR, FIXED, DIPPED SILVER MICA: 33 pF, 5%, 500 volts	3096-513
C30	CAPACITOR, FIXED, CERAMIC: 47 pF, 20%, 500 volts	3111-514
C31	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .22 μF, 10%, 200V	3092-217
C32	Same as C16	
C33, C34	CAPACITOR, FIXED, METALLIZED LACQUER FILM: 1 μF, 10%, 50 volts	3103-34
C35	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .10 μF, 10%, 200V	3092-213
C36	Same as C33	
C37	CAPACITOR, FIXED, CERAMIC: 33 pF, 20%, 500 volts	3111-513
C38	CAPACITOR, FIXED, ELECTROLYTIC: 47 μF, 25 volts	3085-290
C39	Same as C30	
C40	Same as C33	
C41	CAPACITOR, FIXED, CERAMIC: 3300 pF, +50, -20%, 500 volts	3111-525
C42	Same as C30	
C43	Same as C6	
C44	Same as C16	
C45	Same as C31	
C46	CAPACITOR, FIXED, ELECTROLYTIC: 10 μF, 35 volts	3085-336
C47	CAPACITOR, FIXED, SOLID TANTALUM: 150 μF, 20%, 6 volts	3085-352
C48	Same as C16	
C49	Same as C31	
C50	CAPACITOR, FIXED, CERAMIC: 5 pF, ±.25 pF, 500 volts	3110-232
C51	Same as C16	
C52	CAPACITOR, FIXED, ELECTROLYTIC: 5000 μF, 10 volts	3085-337
C53	Same as C16	
C54	Same as C52	
C55, C56	Same as C16	
CR1	SEMICONDUCTOR DEVICE, DIODE: 1N914	3870-175
CR2	SEMICONDUCTOR DEVICE, DIODE: bridge W111	3870-227
DS1	LAMP: pilot, amber, 115V	12270-82
DS2, DS3	LAMP: pilot, clear, 115V	12270-77

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
L1, L2	COIL: .56 μH	3250-503
M1 thru M12	INTEGRATED CIRCUIT: selected	
M13	INTEGRATED CIRCUIT: UL923	9800-26
M14, M15	INTEGRATED CIRCUIT: MC776P	9800-23
M16	INTEGRATED CIRCUIT: MC1027P	9800-24
M17, M18	INTEGRATED CIRCUIT: MC1013P	9800-25
M19	INTEGRATED CIRCUIT: SN7490N	9800-27
Q1	TRANSISTOR: 2N3566	20861-122
Q2	TRANSISTOR: 2N3644	20861-107
Q3	TRANSISTOR: SPS3312	20861-176
Q4	TRANSISTOR: 2N5130	20861-171
Q5	Same as Q1	
Q6	TRANSISTOR: 2N4870	20861-144
Q7	TRANSISTOR: 2N3646	20861-73
Q8, Q9	Same as Q1	
Q10	TRANSISTOR: 2N5139	20861-181
Q11	TRANSISTOR: part of matched pair 20861-207	20861-207
Q12	Same as Q1	
Q13 thru Q16	TRANSISTOR: 2N4258	20861-197
Q17	TRANSISTOR: part of matched pair 20861-207	20861-207
Q18	TRANSISTOR: 2N3904	20861-141
Q19 thru Q21	Same as Q13	
Q22	TRANSISTOR: 2N3569	20861-183
Q23	TRANSISTOR: 2N5179	20861-195
Q24	TRANSISTOR: 2N3563	20861-196
Q25	Same as Q1	
Q26	Same as Q23	
Q27	Same as Q24	
Q28	Same as Q3	
Q29	Same as Q4	
Q30	Same as Q3	
Q31	Same as Q4	
Q32	Same as Q2	
Q33 thru Q35	Same as Q23	
Q36	Same as Q1	
Q37	Same as Q10	
Q38	TRANSISTOR: 2N5040	20861-224
Q39	Same as Q10	
Q40	Same as Q1	
R1	RESISTOR, FIXED, COMPOSITION: 5.6 megohms, 5%, 1/4 watt	18455-561
R2	RESISTOR, FIXED, DEPOSITED CARBON: 100K ohms, 5%, 1/4 watt	18470-104
R3	RESISTOR, FIXED, DEPOSITED CARBON: 1.0K ohms, 5%, 1/4 watt	18470-102
R4	RESISTOR, FIXED, DEPOSITED CARBON: 2.2K ohms, 5%, 1/4 watt	18470-222
R5	RESISTOR, FIXED, DEPOSITED CARBON: 150 ohms, 5%, 1/4 watt	18470-151
R6	RESISTOR, FIXED, DEPOSITED CARBON: 1.5K ohms, 5%, 1/4 watt	18470-152
R7	RESISTOR, FIXED, DEPOSITED CARBON: 330 ohms, 5%, 1/4 watt	18470-331
R8	RESISTOR, FIXED, DEPOSITED CARBON: 33K ohms, 5%, 1/4 watt	18470-333
R9	Same as R3	
R10	RESISTOR, FIXED, DEPOSITED CARBON: 100 ohms, 5%, 1/4 watt	18470-101
R11 thru R14	Same as R8	
R15	RESISTOR, FIXED, DEPOSITED CARBON: 4.7K ohms, 5%, 1/4 watt	18470-472
R16	Same as R3	
R17	Same as R8	
R18	Same as R3	
R19	Same as R8	
R20	Same as R6	
R21	RESISTOR, FIXED, DEPOSITED CARBON: 10K ohms, 5%, 1/4 watt	18470-103
R22	RESISTOR, FIXED, DEPOSITED CARBON: 56K ohms, 5%, 1/2 watt	18526-17
R23	RESISTOR, FIXED, DEPOSITED CARBON: 1 megohm, 5%, 1/4 watt	18470-105
R24	RESISTOR, FIXED, COMPOSITION: 1.8 megohms, 5%, 1/4 watt	18455-181
R25	Same as R15	
R26	RESISTOR, FIXED, DEPOSITED CARBON: 3.3K ohms, 5%, 1/4 watt	18470-332
R27, R28	Same as R3	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R29	RESISTOR, FIXED, DEPOSITED CARBON: 15 ohms, 5%, 1/4 watt	18470-150
R30	RESISTOR, FIXED, DEPOSITED CARBON: 68 ohms, 5%, 1/4 watt	18470-680
R31	Same as R2	
R32	RESISTOR, VARIABLE: composition, 1 megohm, 20%, 1/2 watt, spst switch	16925-570
R33	Same as R6	
R34	Same as R21	
R35	RESISTOR, FIXED, DEPOSITED CARBON: 56K ohms, 5%, 1/4 watt	18470-563
R36	RESISTOR, FIXED, DEPOSITED CARBON: 560 ohms, 5%, 1/4 watt	18470-561
R37	Same as R6	
R38	RESISTOR, FIXED, DEPOSITED CARBON: 2.7K ohms, 5%, 1/4 watt	18470-272
R39	RESISTOR, FIXED, DEPOSITED CARBON: 220 ohms, 5%, 1/4 watt	18470-221
R40	RESISTOR, FIXED, METAL FILM: 909K ohms, 1%, 1/2 watt	18525-886
R41	RESISTOR, FIXED, METAL FILM: 90.9K ohms, 1%, 1/2 watt	18525-926
R42	RESISTOR, FIXED, METAL FILM: 10K ohms, 1%, 1/2 watt	18525-910
R43	Same as R2	
R44	RESISTOR, FIXED, DEPOSITED CARBON: 39 ohms, 5%, 1/4 watt	18470-390
R45	Same as R6	
R46	Same as R44	
R47	Same as R7	
R48	Same as R38	
R49	RESISTOR, FIXED, DEPOSITED CARBON: 10 ohms, 5%, 1/4 watt	18470-100
R50	RESISTOR, FIXED, DEPOSITED CARBON: 680 ohms, 5%, 1/4 watt	18470-681
R51	Same as R7	
R52	Same as R49	
R53	Not used	
R54	Same as R50	
R55	RESISTOR, FIXED, DEPOSITED CARBON: 360 ohms, 5%, 1/4 watt	18470-361
R56	Same as R6	
R57	Same as R49	
R58	Same as R8	
R59	RESISTOR, FIXED, DEPOSITED CARBON: 47K ohms, 5%, 1/4 watt	18470-473
R60	RESISTOR, VARIABLE: composition, 10K ohms, 30%, 1/2 watt	16925-538
R61	Same as R23	
R62	Same as R4	
R63	RESISTOR, FIXED, DEPOSITED CARBON: 27 ohms, 5%, 1/4 watt	18470-270
R64, R65	Same as R4	
R66	Same as R5	
R67	RESISTOR, FIXED, DEPOSITED CARBON: 47 ohms, 5%, 1/4 watt	18470-470
R68	RESISTOR, FIXED, DEPOSITED CARBON: 910 ohms, 5%, 1/2 watt	18526-15
R69	Same as R63	
R70	Same as R5	
R71	RESISTOR, FIXED, DEPOSITED CARBON: 2.2K ohms, 5%, 1/2 watt	18526-16
R72	RESISTOR, FIXED, DEPOSITED CARBON: 180 ohms, 5%, 1/4 watt	18470-181
R73	Same as R50	
R74	Same as R72	
R75	RESISTOR, FIXED, DEPOSITED CARBON: 6.8K ohms, 5%, 1/4 watt	18470-682
R76	RESISTOR, FIXED, DEPOSITED CARBON: 2.0K ohms, 5%, 1/4 watt	18470-202
R77	Same as R72	
R78	RESISTOR, FIXED, DEPOSITED CARBON: 270 ohms, 5%, 1/4 watt	18470-271
R79	Same as R72	
R80	Same as R38	
R81	RESISTOR, FIXED, DEPOSITED CARBON: 470 ohms, 5%, 1/4 watt	18470-471
R82	Same as R50	
R83	Same as R24	
R84	Same as R23	
R85	Same as R6	
R86	Same as R23	
R87	Same as R22	
R88	Same as R24	
R89	Same as R7	
R90	RESISTOR, FIXED, DEPOSITED CARBON: 1.2K ohms, 5%, 1/4 watt	18470-122
R91	Same as R38	
R92, R93	Same as R39	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R94	Same as R3	
R95, R96	Same as R7	
R97	Same as R90	
R98	Same as R15	
R99	Same as R50	
R100	Same as R26	
R101	RESISTOR, FIXED, DEPOSITED CARBON: 2.4K ohms, 5%, 1/4 watt	18470-242
R102	Same as R2	
R103	Same as R81	
S1	Part of R32	
S2	SWITCH: slide, spdt	19911-103
S3	SWITCH: push type, 9 button	19910-203
S4	SWITCH: push type, 4 button	19910-202
T1	TRANSFORMER	20800-359
Y1	CRYSTAL: 2 Mc	3870-228
	BOOKLET: instructions	2490-589
	KNOB: black	11505-171

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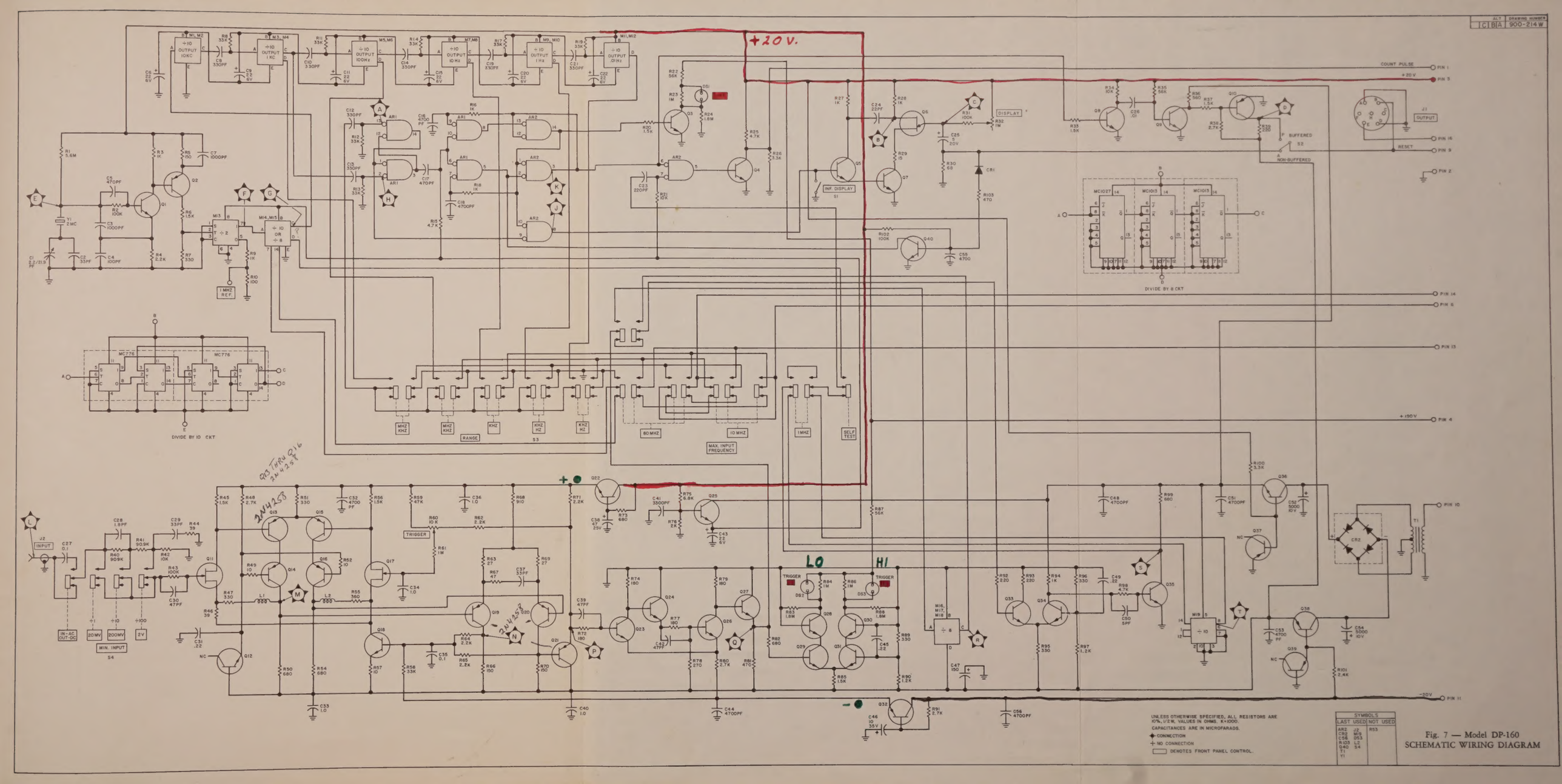

Fig. 7 — Model DP-160
SCHEMATIC WIRING DIAGRAM